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Mobility Data Decentralisation leveraging Galileo and Blockchain

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1. Introduction

Urban mobility is gaining an ever-increasing importance in today's society due to the growing population movements toward big cities and the exponential growth of cities in developing countries. The landscape of urban mobility is evolving even faster due to a combination of social, economic, and technological changes. Traditional means of urban transportation like walking, taking public transportation, taxis or private cars have now been extended by a wide range of new, more flexible mobility services, such as vehicle sharing, ride-hailing, and carpooling.

Geolocation plays a key role in this growing mobility ecosystem. The use of positioning technologies for the geolocation of vehicles and final users' smartphones represents a key enabler for more efficient planning and operating mobility services. Without this technology, many mobility service providers simply could not operate efficiently, if at all; and the rest that could operate would do so with a significantly lower quality of experience.

Users expect and demand more, higher-quality mobility services in an improved and seamless mobility experience. Therefore, the accuracy of the geolocation signal and other features that we describe throughout this paper are key enablers to the adequate functioning of any service. In this context, the incorporation of **Galileo positively impacts many existing applications in urban mobility and opens the way for new services and better adoption in cities.**

The other side of the coin is how the data is stored, distributed, and used in a way that maximises its utility to society. The *statu quo* is each service collecting data on its vehicles, and processing and storing it in its own isolated computer infrastructure, which is selectively shared, often via non-standard data formats and APIs. This situation leads to service fragmentation, as there is no infrastructure to interoperate with such data and services with a common interface (neither at the APIs nor the user interface levels).

In this paper, we present a platform, developed in the context of the EC-funded project MOLIERE[1] , that combats this issue by building on a combination of public and private blockchain infrastructure as a high-potential enabler. **The key advantage that blockchain technology provides is that it offers building blocks to create neutral, common-ground infrastructure that can be owned by a consortium of organizations (private blockchains) or as a true "commons" owned by the public (public blockchains) where stakeholders with an interest in maintaining, using and improving its infrastructure govern it.**

[1] The MOLIERE project (https://moliere-project.eu) has received funding from the European Agency for the Space Programme (EUSPA) under Grant Agreement No 101004275

The MOLIERE architecture enables mobility ecosystems to organise around a blockchain layer that facilitates data publication, enrichment / rectification, its selective distribution, the creation of protocols for data exchange and operations such as booking reservations of mobility services, thereby maximizing the utility of the data obtained and contributed by all parties (and the mobility services they provide).

Mobility services operate their services in overlapping areas to form mobility networks that citizens rely on for their mobility needs. The various mobility services operate in coopetition (defined as "the act of cooperation between competing companies").

It is rather easy to think of mobility firms that are apparently in frontal competition; for example, taxi companies in the same city often offer essentially interchangeable services at the same prices. It is also just as easy to identify examples of clearly complementary mobility services. For example, scooters can provide first and last mile coverage for trips enabled by long-distance rail.

It is tempting to perceive many services as competitors, but this is so only in a very narrow interpretation of the concept. Even mobility services that are closest in their service offerings (and therefore often compete for certain users) in practice cooperate to provide wider or higher-quality coverage in an area, e.g., they provide vehicles that are closer to a citizen, or they better serve their needs depending on their unique and changing needs.

To illustrate this point, picture a city with a single small micromobility operator that has a few dozen scooters scattered throughout its neighbourhoods. This city would clearly be better served by many such small operators instead. Despite the apparent competition between such operators, in the aggregate, they can be considerably more successful when operating simultaneously in apparent competition: users will tend to rely more on them if they know a close vehicle will almost always be available, whereas if only a small operator existed, they would tend to form alternative travel plans, as they would not be able to rely on it. Similar arguments can be extended to other modes; for example, a citizen may decide not to buy a car if sufficient vehicle sharing alternatives exist, even if at times, companies can be competing to serve a given user.

As of today, with a few exceptions, mobility services of different companies are not tightly connected nor integrated. Mapping applications are as of today pervasive, and they do allow users to plan their journeys, especially on public transport - but they do not offer direct access to book and pay for such services (for example, they require external apps or the use of kiosks for booking), nor do they contain the ever-increasing full range of mobility services that are available to citizens.

2. Objectives of MOLIERE's Mobility Data Marketplace

As argued, mobility services nowadays are largely disconnected and do not allow interoperation, especially those operated by different companies.

The main objective of MOLIERE is to create a technical infrastructure that enables seamless, interoperable mobility. We call it "Mobility Data Marketplace" (MDM), a platform that is able to ingest data from mobility services in a standardised format. This way, the MDM enables the seamless integration of mobility experiences, in an environment where such services are provided by companies that are largely independent and operate in a com-petitive environment.

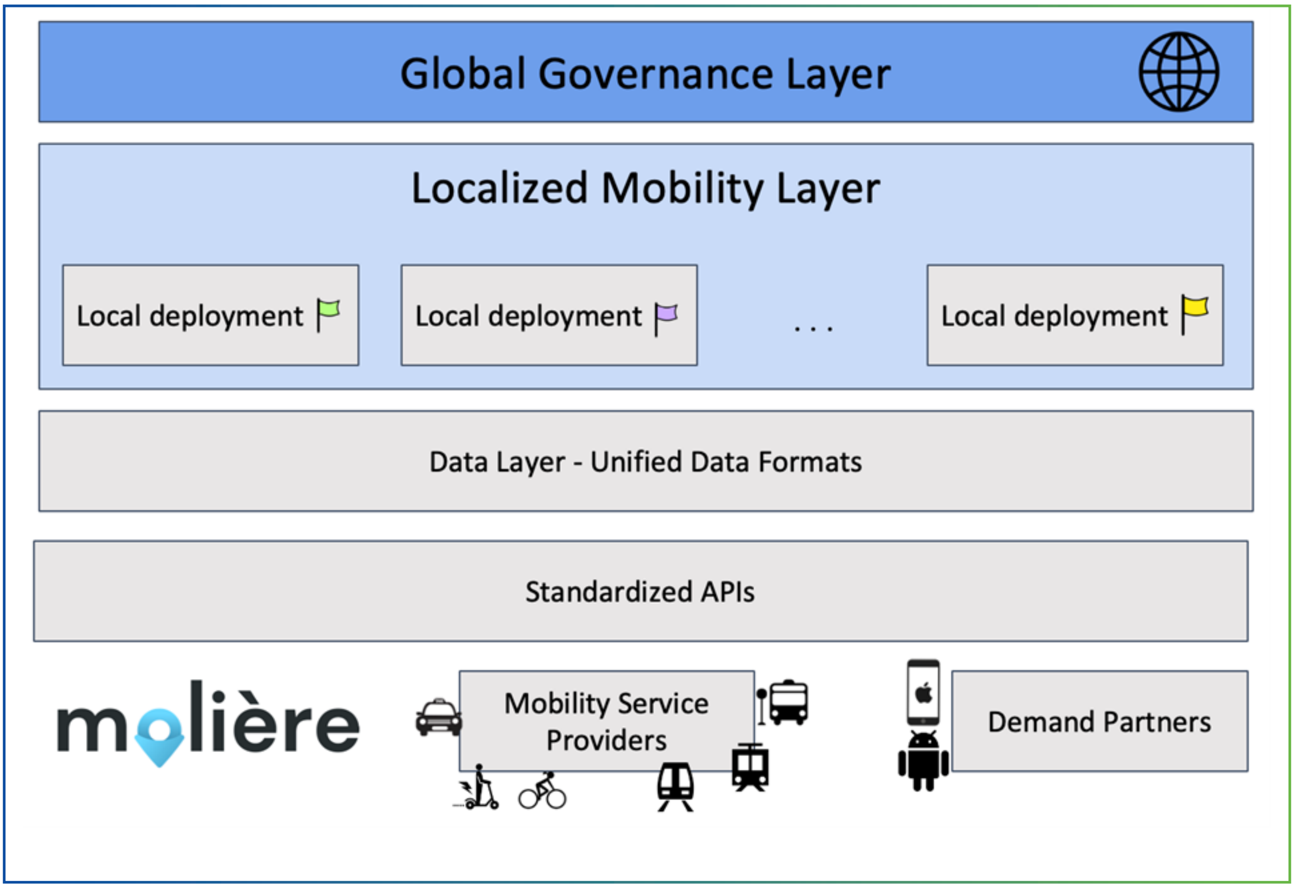
The integration of mobility experiences is defined as the ability for users to, from a single user interface, 1) discover mobility services they were not fully aware of; 2) combine mobility services as required to form potentially multimodal trip plans, leveraging routing algorithms; 3) book these mobility services, again from a single user interface, i.e., not having to hop around apps or other interfaces to obtain reservations or access to vehicles; and finally 4) pay for such mobility services. This is well aligned with the high-level objectives of the MOLIERE project, where several use cases will demonstrate the potential of the MDM that is sourced with mobility data where the geolocation component leverages Galileo:

Ultimately, the strategic vision of the MOLIERE architecture is to become a commons, that is, an infrastructure that is a common good that is not under the control of a single company or organisation, but a coalition of stakeholders that are interested in its success. This introduces important design constraints, since traditional architectures (e.g., centrally hosted Software-as-a-Service approaches) always remain under the control of a single operator. Instead, MOLIERE's MDM relies on public blockchain technology. At the same time, MOLIERE's design aims to be practically implementable in the real world, and as such needs to be mindful of data privacy regulations, and

and therefore, not all of the MDM is implemented using public blockchain infrastructure.

3. MOLIERE's Architecture

The architecture of MOLIERE's Mobility Data Marketplace (MDM) is based on two separate layers, called the Governance and the Mobility layers. The Governance layer enables the stakeholders of the MDM to make decisions about the infrastructure, including where it runs, and how the mobility layer is structured. In contrast, the Mobility layer is what stores actual data related to mobility services, and where the purchase of mobility services is facilitated. The high-level architecture of the MDM can be observed in the diagram below:



3.1 Governance Layer

MOLIERE's MDM aims to be a commons infrastructure that is governed by the stakeholders with an interest in its correct operation and maintaining its utility. The MDM clearly will require upgrades, in terms of functionality and the underlying computing infrastructure, just like any computing platform.

A key feature of MOLIERE's MDM is that the Mobility layer is split in jurisdictional domains. One of the key functions of the Governance Layer is therefore to partition the world in such domains, and to appoint computing nodes that will host the mobility layer in each area of the world, in a way again later described in this paper.

The Governance Layer is implemented as a public Cosmos application-specific blockchain (Cosmos app chain for short). The implementation of this governance function in a public blockchain has advantages such as its fairness and radical transparency, since each decision, vote, or transfer of stake between parties is immutably recorded in a publicly verifiable and auditable ledger, as well as its equal openness and inclusiveness towards all stakeholders. Additionally, a Cosmos app chain allows upgrading its core functionality as required, and is extremely power efficient, since it runs on Proof of Stake (PoS)[2] consensus, rather than the power-intensive Proof of Work (PoC)[3] (for example, Ethereum reduced emissions by an estimated 99.992% by switching from Proof of Work to Proof of Stake [CCRI-Merge]).

A very flexible way to achieve an open governance model is to adopt token-based governance, where stake in the system is represented by a token held on a public blockchain: in this case, the MOLIERE app chain. The governance decisions outlined above are then made via token weighted voting. Our implementation of votes relies on standard functionality included in the Cosmos SDK [Cosmos-SDK].

Such token-weighted votes are then used to maintain a list of approved geographical areas. Another key governance mechanism is to decide which computing nodes shall then host the required infrastructure for the Mobility Layer to be run for each approved geographical area. This decision is too based on a token weighted vote.

The voting mechanism is based not on tokens owned, but on tokens staked on the network. This forces those who participate in decision making to experience the economic consequences of decisions on the value of their tokens, i.e., it forces them to have skin in the game [Buterin-Gov].

Clearly, the governance function of MOLIERE is valuable if MOLIERE itself is valuable. This means that, in turn, the governance tokens must have non-zero value. This introduces the opportunity to fund the development of the infrastructure by minting tokens and awarding them to organizations that contribute to its growth; for example, the development of new features of the platform, or its deployment and promotion in new geographical areas. This idea is further explored in a later section.

[2] https://ethereum.org/en/developers/docs/consensus-mechanisms/pos/

[3] https://ethereum.org/en/developers/docs/consensus-mechanisms/pow/

3.2 Mobility Layer

While the Governance Layer is in charge of making decisions about the maintenance and improvement of the MDM, the Mobility Layer is in charge of ingesting, processing, and offering access to data on mobility services, with the end goal of facilitating the discovery, combination, booking and payment of mobility services.

Blockchain technology. The Mobility Layer is also designed as a Cosmos application blockchain. However, in contrast to the Governance Layer, it runs on a private blockchain, instead of a public one. This means that access to the data is carefully restricted on a need-to-know basis. For example, end-users can discover the mobility services and book them, but each end-user can only access their own bookings, while mobility companies can only access any user's bookings of their own services.

The Mobility Layer cannot run on public blockchains where all on-chain data is freely accessible; this would make it impossible to meet the privacy expectations of end-users, even if they hold only pseudonymous identities; it would publish excessive information on the mobility patterns of end-users in a public, immutable record, making it impossible to implement operations such as GDPR's rights to data erasure.

What is the advantage of running on a private blockchain, as opposed to a fully privately hosted infrastructure? A first advantage is that the Governance Layer can easily decide which node operators are approved for each geographical area. This decision can be made based on the reputation of such nodes and their value adds; for example, certain jurisdictions consider mobility infrastructure a strategic asset that must be hosted within its borders, and privacy regulations also advise local computing resources to be used. Decisions can also be made with other criteria, such as activities taken by the node operator to promote the use of the system.

A second advantage of running on a private blockchain is that node operators cross-verify their work. A blockchain therefore introduces checks and balances that fully centralised systems do not feature; instead, the correct operation of the system is delegated to a single organisation, which grants excessive power to the operator of the infrastructure.

Finally, a private blockchain very naturally allows participants to be appointed or excluded dynamically by the Governance Layer, without the need to organise complex data transfers between organizations.

In summary, compared to a public blockchain, where all participants can fully audit the work of all nodes, a private blockchain offers less guarantees of security and fairness. However, it does offer better guarantees than a fully privately operated system, and it allows nodes to be rotated to more suitable organizations; for this reason, we believe this design offers a good trade-off between security and data privacy requirements.

API and data formats. The Mobility Layer features an API for third parties to push information about the mobility services they operate, including the availability and status of such services, and for end-users to discover such services, as well as book and pay for them. This API is implemented in the gRPC framework [GRPC], with all the data formats defined in Protocol Buffers. This offers a high-performance, data-efficient, strongly typed API specification, which can easily be translated to an arguably more widely usable RESTful HTTP API, but can also be used to easily generate robust, native clients in several mainstream programming languages.

Meta-services. The Mobility Layer also offers value-added services, such as a geocoding API, a data crowdsourcing module, and most notably, a router which implements a journey planner that includes all the mobility services integrated in the MDM. Another important meta-service automatically monitors and ingests data feeds in de-facto standards, most notably including GTFS and its real-time variants, and GBFS.

API Adaptors. Besides the aforementioned data feed standards, there is a lack of standardisation of the APIs to enable the bookings of mobility services, perhaps with the notable exception of the TOMP API[4], which is not as of today yet widely adopted. For this reason, in order for the MDM to function, mobility service operators must write API adaptors that bridge their proprietary APIs to the API specifications of the MDM. This enables full interoperability within the MDM.

4. Economic Incentives

As a novel mobility marketplace, MOLIERE requires incentives to promote its own growth.

A mobility marketplace experiences the two-sided marketplace problem, where, initially, providers see no benefit in incurring the costs of integrating a marketplace that has a lack of users and, simultaneously, users will not sign up to a mobility marketplace that has few providers. These concerns obviously disappear once the marketplace gains a certain momentum, with a critical mass of both providers and users. In a scenario where MOLIERE is established as a global mobility infrastructure, it is in the best interest of providers to join it to access a massive number of end-users, and, conversely, users naturally gravitate to it, as it offers more mobility services than any other venue.

A way to break this barrier is to consider what incentives can be offered to stakeholders interested. This section explores the intrinsic incentives for stakeholders to adopt the platform and what additional incentives the platform can provide to encourage its growth, especially early on, when its network effects are not large enough to justify the effort to adopt the platform.

[4] Transport Operator to Mobility-as-a-Service Provider (TOMP) https://github.com/TOMP-WG/TOMP-API

As explained in the previous section, the token that governs the MDM must be valuable if the MDM itself is. This creates an opportunity to leverage the token to provide economic incentives for the growth of the MDM. An answer to this lack of incentives to connect to the MDM is the creation of incentives via the awarding of governance tokens to those companies who actually connect to the network and participate in the delivery of quality mobility services.

These incentives can be offered to mobility companies that integrate the marketplace, but also other stakeholders, such as node operators or other parties that perform a task in promoting the adoption of the marketplace, and front-end applications, usually mobile apps, that bring end-users to the marketplace.

The network as a whole, then, periodically reviews the mobility services exchanged on the network, and computes a reward for each involved party as a function of the number of mobility services participated in, the area where these services are rendered, the value of the service, or other factors that the token holders who invest in the network's governance deem of importance. Then, this reward is awarded to each stakeholder.

One of the key aspects to incentivising growth in a decentralized network is to avoid bad players (attackers who can almost certainly participate in the system due to its decentralised nature) misreporting or pretending to deliver mobility services just to capture rewards.

Completely removing the possibility of fraud could only be achieved via combining "proofs" of the existence of a vehicle, its location and how it changes over time, and in fact that one mobility service (and only one single mobility service) was rendered and paid for in connection with the movement of the vehicle by a real person. The MDM combats such attacks by introducing a novel "Proof of Mobility" service, which allows a third party to attest to the fact that a vehicle moved in accordance with the services that its operator reported.

Moreover, with Galileo's unique Open Service Navigation Message Authentication (OSNMA), a data authentication function for the Galileo Open Service worldwide users, freely accessible to all, GNSS receivers obtain the assurance that the received Galileo navigation message is coming from the system itself and has not been tampered with.

For example, an app can request a taxi from points A to B. The app captures this information from the end-user's device. Then, the Mobility Service Provider (MSP) also captures it. Likewise, the node that interconnected the app and the MSP too records this information. Then any party with access to these signatures can at least attest that all parties agree a service was performed. Note that all this information can be stored on the private blockchain for auditability.

5. Conclusions

In this paper we have introduced the architecture of the MOLIERE Mobility Data Marketplace (MDM) as a commons infrastructure that has the objective of alleviating the issues caused by the fragmentation of mobility services that is nowadays pervasive.

The MDM can receive information on mobility services and make them available via standardised APIs to third-party user interfaces, which can, via the MDM, discover, combine, book and pay for mobility services from a single user interface.

The main novelty of the MDM is that it runs on a decentralised architecture that combines a token-based governance mechanism on a public blockchain with territorially bounded deployments of its mobility layer, based on private blockchains. This combination of technologies allows the MDM to be effectively decentralised, while allowing for its customization for each region, usually but not only due to regulatory issues.

The MOLIERE project is developing use cases that showcase the power of the MDM, including a MaaS style application and a rich meta information service that displays cycle lanes quality.

References

i. [Buterin-Gov] Vitalik Buterin: "Moving beyond coin voting governance", https://vitalik.ca/general/2021/08/16/voting3.html (2021).

ii. [CCRI-Merge] Crypto Carbon Ratings Institute: "The Merge - Implications on the Electricity Consumption and Carbon Footprint of the Ethereum Network", https://carbon-ratings.com/eth-report-2022 (2022).

iii. [Cosmos] Jae Kwon, Ethan Buchman: "A Network of Distributed Ledgers", https://v1.cosmos.network/resources/whitepaper (2022).

iv. [Cosmos-SDK] Cosmos: "The Cosmos SDK Documentation", https://docs.cosmos.network/main (2022)

v. [GRPC] gRPC: "gRPC—A High-Performance Open-Source Universal RPC Framework." https://grpc.io/ (2020).

vi. [Julliena] Bruno Julliena, Alessandro Pavan, Marc Rysmand: "Two-sided markets, pricing, and network effects". Handbook of Industrial Organization, Volume 4, Issue 1, 2021, Pages 485-592.

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